



# Acid Rain Program 2004 Progress Report



10 YEARS OF ACHIEVEMENT

# Acid Rain Program 2004 Progress Report

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EPA publishes an annual report to update the public on compliance with the Acid Rain Program, the status of implementation, and progress toward achieving environmental goals. Because this report builds upon and updates previous reports, those who are new to the program might find it helpful to first read some background material on the EPA Web site at [www.epa.gov/airmarkets/arp](http://www.epa.gov/airmarkets/arp).

The *Acid Rain Program 2004 Progress Report* updates data reported in previous years, specifically:

- Sulfur dioxide (SO<sub>2</sub>) emissions, allowance market information, and program compliance.
- Nitrogen oxides (NO<sub>x</sub>) emissions and program compliance.
- Status and trends in acid deposition, air quality, and ecological effects.
- Benefits and costs of the Acid Rain Program.

This report marks the 10th year of the Acid Rain Program by highlighting some of the major developments that have occurred over that time, including advances in emission controls, improvements in program management, and electronic delivery of services, and maturity of the program's allowance trading market.

For more information on the Acid Rain Program, including additional information on SO<sub>2</sub> and NO<sub>x</sub> emissions, acid deposition monitoring, environmental effects of acid deposition, and detailed unit-level emissions data, please visit EPA's Clean Air Markets Web site at [www.epa.gov/airmarkets](http://www.epa.gov/airmarkets).

## Summary

Sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>) are the key pollutants in the formation of acid rain. These pollutants also contribute to the formation of fine particles (sulfates and nitrates) that are associated with significant human health effects and regional haze. Additionally, NO<sub>x</sub> combines with volatile organic compounds (VOCs) to form ground-level ozone (smog) and nitrates that are transported and deposited at environmentally detrimental levels in parts of the country. In the United States, the electric power industry accounts for nearly 70 percent of total annual SO<sub>2</sub> emissions and slightly more than 20 percent of total annual NO<sub>x</sub> emissions.

The Acid Rain Program was created to implement Title IV of the 1990 Clean Air Act Amendments. The purpose of Title IV is to reduce the adverse effects of acid deposition through reductions in annual emissions of SO<sub>2</sub> and NO<sub>x</sub> by 10 million tons and by 2 million tons below projected levels, respectively.

Since the start of the Acid Rain Program in 1995, the lower SO<sub>2</sub> and NO<sub>x</sub> emission levels from the power sector have contributed to significant air quality and environmental and human health improvements. The 2004 compliance year marked the 10th year of the program. During that period, the Acid Rain Program has:

- Reduced SO<sub>2</sub> emissions by over 5 million tons from 1990 levels, or about 34 percent of total emissions from the power sector. Compared to 1980 levels, SO<sub>2</sub> emissions from power plants have dropped by 7 million tons, or more than 40 percent.
- Cut NO<sub>x</sub> emissions by about 3 million tons from 1990 levels, so that emissions in 2004 were less than half the level anticipated without the program. Other efforts, such as the NO<sub>x</sub> Budget Trading Program in the eastern United States, also contributed significantly to this reduction.
- Led to significant cuts in acid deposition, including reductions in sulfate deposition of about 36 percent in some regions of the United States and improvements in environmental indicators, such as fewer acidic lakes.
- Provided the most complete and accurate emission data ever developed under a federal air pollution control program and made that data available and accessible by using comprehensive electronic data reporting and Web-based tools for agencies, researchers, affected sources, and the public.
- Served as a leader in delivering e-government, automating administrative processes, reducing paper use, and providing online systems for doing business with EPA.
- Resulted in nearly 100 percent compliance through rigorous emissions monitoring, allowance tracking, and an automatic,

### Acid Rain Program 1995–2005: From Grand Policy Experiment to Demonstrated Results

Congress created the Acid Rain Program's SO<sub>2</sub> emissions cap-and-trade approach in 1990 amid uncertainty that the innovative, market-based control program would work. Since the program's implementation, air pollution control experts from a wide range of perspectives agree that it is one of the most successful environmental programs in U.S. history. The program serves as a model for a new generation of regional and national control programs, such as the 2005 Clean Air Interstate Rule (CAIR). A 2005 study estimates that in 2010, the Acid Rain Program's annual benefits will be approximately \$122 billion (2000\$), at an annual cost of about \$3 billion—a 40-to-1 benefit-to-cost ratio.

easily understood penalty system for noncompliance. Flexibility in compliance strategies reduced implementation costs.

Building on the Acid Rain Program model, EPA promulgated the Clean Air Interstate Rule (CAIR)

in March 2005, to address transport of fine particles and ozone in the eastern United States, the Clean Air Mercury Rule (CAMR) to reduce nationwide mercury emissions from power plants, and the Clean Air Visibility Rule (CAVR) to improve visibility in national parks and wilderness areas.

## Origins of the Acid Rain Program

Acid deposition, more commonly known as acid rain, occurs when emissions of  $\text{SO}_2$  and  $\text{NO}_x$  react with water, oxygen, and oxidants in the atmosphere to form various acidic compounds. Prevailing winds transport the acidic compounds hundreds of miles, often across state and national borders, where they impair air quality and damage public health, acidify lakes and streams, harm sensitive forest and coastal ecosystems, degrade visibility, and accelerate the decay of building materials.

The Acid Rain Program, established under Title IV of the 1990 Clean Air Act Amendments, requires major reductions of  $\text{SO}_2$  and  $\text{NO}_x$  emissions from the electric power industry. The  $\text{SO}_2$  program sets a permanent cap on the total amount of  $\text{SO}_2$  that may be emitted by electric power plants in the contiguous United States. The program is phased in, with the 2010  $\text{SO}_2$  cap set at about one-half of the 1980 emissions from the power sector.

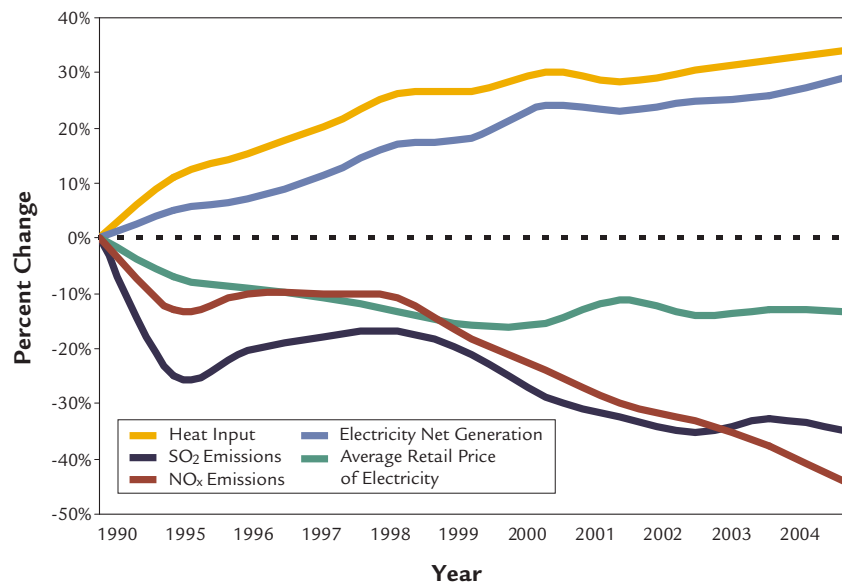
As seen in Figure 1, emissions of both  $\text{SO}_2$  and  $\text{NO}_x$  have fallen significantly at the same time as combustion of fossil fuel (coal, oil, or natural gas), measured as “heat input,” for electricity generation, has increased. The increase in electricity generation has not only been achieved at lower emission levels, it has occurred while the real retail price of electricity has fallen.

Using a market-based cap and trade mechanism to reduce  $\text{SO}_2$  emissions allows flexibility for individual fossil fuel-burning units at electric

power plants regulated under the Acid Rain Program to select their own methods of compliance. Currently, one allowance provides a limited authorization to emit one ton of  $\text{SO}_2$ . The Clean Air Act allocated allowances to regulated units based on historic fuel consumption and specific emission rates prior to the start of the program. The total allowances allocated for each year equal the  $\text{SO}_2$  emissions cap. The program encouraged early reductions by allowing sources to bank unused allowances in one year and use them in a later year.

The program uses a more traditional approach to achieve  $\text{NO}_x$  emission reductions. Rate-based limits apply to most of the coal-fired electric utility boilers subject to the Acid Rain Program. The program does not establish a cap on  $\text{NO}_x$  emissions;

**Figure 1. Trends in Electricity Generation and Emissions from Electric Power Sources**



**Sources:** EPA (heat input and emissions) and Energy Information Administration (electricity generation and price values).

**Note:** Heat input and emissions data reflect Acid Rain Program units. Generation reflects all fossil fuel-fired electricity-only plants in the United States. Retail price reflects full national values for the electricity-generating sector.

## SO<sub>2</sub> Emission Reductions from Acid Rain Program Sources: A Decade of Cost-Effective Progress

In 1995, the first year of implementation, SO<sub>2</sub> emissions decreased by 24 percent—nearly 4 million tons—from 1990 levels.

During the past decade, SO<sub>2</sub> emissions dropped an additional 13 percent from 1995 levels despite a 20 percent increase in utilization (based on heat input).

In 2004, SO<sub>2</sub> emissions from all Acid Rain Program units totaled 10.3 million tons, a 34 percent decrease from 1990 levels (15.7 million tons).

Until SO<sub>2</sub> allowance prices began to increase in 2004 in anticipation of EPA's 2005 Clean Air Interstate Rule (CAIR), allowance prices generally remained under \$200/ton, well below expected control costs for the program.



instead, it is designed to achieve a 2 million ton reduction from projected 2000 NO<sub>x</sub> emission levels without implementation of Title IV.

The Acid Rain Program is composed of two phases for SO<sub>2</sub> and NO<sub>x</sub>. Phase I applied primarily to the largest coal-fired electric generation sources from 1995 through 1999 for SO<sub>2</sub> and from 1996 through 1999 for NO<sub>x</sub>. Phase II for both pollutants began in 2000. In 2004, the SO<sub>2</sub> Phase II requirements applied to 3,391 operating units; the Phase II NO<sub>x</sub> requirements applied to 989 operating units that burned coal from 1990 to 1995.

## SO<sub>2</sub> Emission Reductions

Electric power generation is by far the largest single source of SO<sub>2</sub> emissions in the United States, accounting for nearly 70 percent of total SO<sub>2</sub> emissions nationwide.<sup>1</sup>

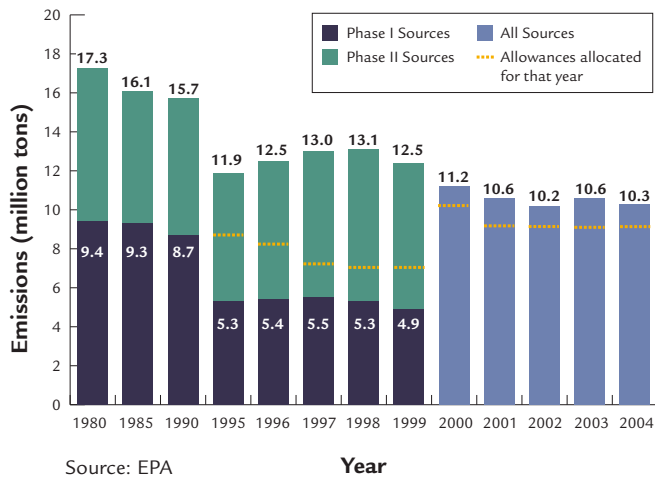
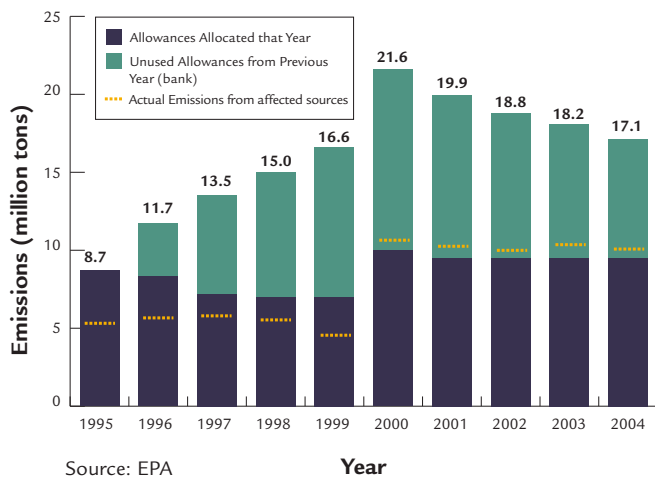
In 2004, 3,391 operating units were subject to the SO<sub>2</sub> provisions of the Acid Rain Program. As shown in Figure 2, Acid Rain Program sources have reduced annual SO<sub>2</sub> emissions by 40 percent compared to 1980 levels and 34 percent compared to 1990 levels. Reductions in SO<sub>2</sub> emissions from other sources not affected by the Acid Rain Program, including industrial and commercial boilers and the metals and refining industries, and use of cleaner fuels in residential and commercial burners, have also contributed to an even greater decline (45 percent) in annual SO<sub>2</sub> emissions from all sources since 1980 (see [www.epa.gov/airtrends](http://www.epa.gov/airtrends)).

For 2004, EPA allocated a total of 9.5 million SO<sub>2</sub> allowances under the Acid Rain Program. Adding these allowances to the 7.6 million unused allowances carried over (or banked) from prior years, there were 17.1 million allowances available for use in 2004. Sources emitted 10.3 million tons of SO<sub>2</sub> in 2004, somewhat more than the allowances allocated for the year but far less than the total allowable level (see Figure 3).<sup>2</sup>

The number of banked allowances dropped from 7.58 million available for 2004 compliance, to 6.86 million available for compliance in 2005 and future years. This reduction amounts to 9.5 percent of the total bank. Over time, the bank is expected to continue to be depleted as sources use banked allowances to comply with the stringent Phase II requirements. In 2010, the annual total number of allowances allocated drops to 8.95 million (about half of the emissions from the power industry in 1980) and remains statutorily fixed at that annual level permanently. Figure 4 explains in more detail the origin of the allowances that were available for use in 2004, and Figure 9 (on page 8) shows how those allowances were used.

<sup>1</sup> National Emission Inventory 2002: [www.epa.gov/ttn/chief/trends/index.html](http://www.epa.gov/ttn/chief/trends/index.html).

<sup>2</sup> Detailed emissions data for Acid Rain Program sources are available on the Data and Maps portion of EPA's Clean Air Markets Web site at [www.epa.gov/airmarkets](http://www.epa.gov/airmarkets).

Figure 2: SO<sub>2</sub> Emissions under the Acid Rain ProgramFigure 3: SO<sub>2</sub> Emissions and the Allowance Bank, 1995–2004

The states with the highest-emitting sources in 1990 have seen the greatest SO<sub>2</sub> reductions during the Acid Rain Program. Most of these states are upwind of the areas the Acid Rain Program was designed to protect, and reductions have resulted in important environmental and health benefits over a large regional scale (see Figure 5 on page 6). In addition, the states that reduced emission from 1990 to 2004 had total annual reductions of approximately 5.9 million tons, while the states that had increased emissions—largely attributable to growth and not increases in emission

Figure 4: Origin of 2004 Allowable SO<sub>2</sub> Emission Levels

Type of Allowance Allocation	Number of SO <sub>2</sub> Allowances	Explanation of Allowance Allocation Type
Initial Allocation	9,191,897	Initial allocation is the number of allowances granted to units* based on the product of their historic utilization and emission rates specified in the Clean Air Act.
Allowance Auction	250,000	The allowance Auction provides allowances to the market that were set aside in a Special Allowance Reserve when the initial allowance allocation was made.
Opt-in Allowances	99,188	Opt-in allowances are provided to units entering the program voluntarily. There were 11 opt-in units in 2004.
<b>Total 2004 Allocation</b>	<b>9,541,085</b>	
Total Banked Allowances	7,574,959	Banked allowances are those allowances accrued in a unit's account from previous years, which can be used for compliance in 2004 or any future year.
<b>Total 2004 Allowable Emissions</b>	<b>17,116,044</b>	

Source: EPA

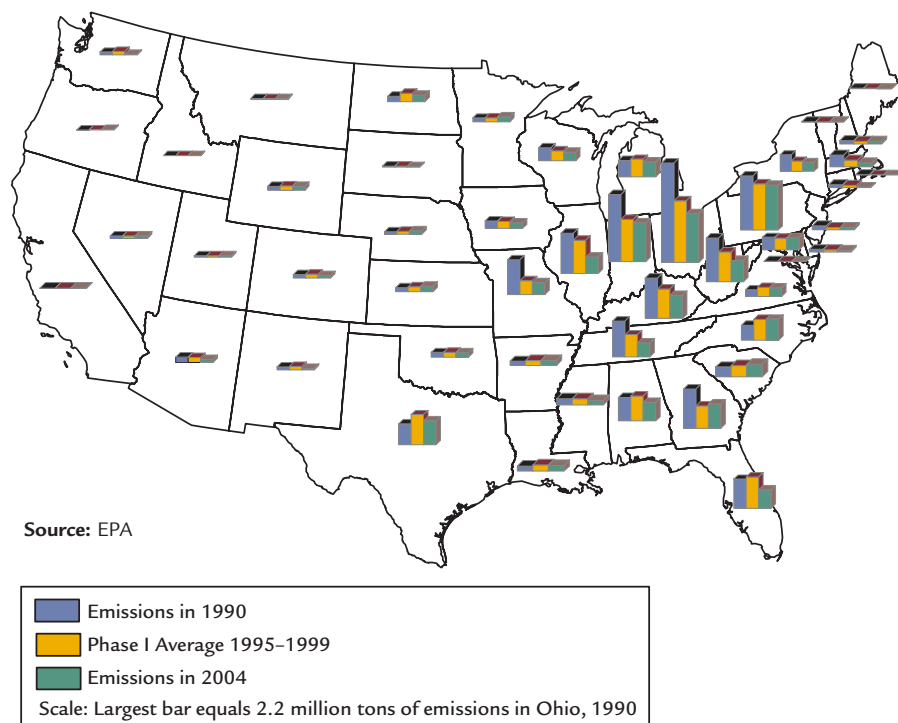
\*Note: In this report, the term “unit” means a fossil fuel-fired combustor that serves a generator that provides electricity for sale. The vast majority of SO<sub>2</sub> emissions affected by the program come from coal-fired generation units, but oil and natural gas units are also included in the program.

rates—had much smaller annual increases (a total increase of approximately 430,000 tons).

For 32 states and the District of Columbia, annual SO<sub>2</sub> emissions in 2004 were lower than emissions in 1990. Among these states, 13 decreased their annual emissions by more than 100,000 tons between 1990 and 2004:

Alabama, Florida, Georgia, Illinois, Indiana, Kentucky, Massachusetts, Missouri, New York, Ohio, Pennsylvania, Tennessee, and West Virginia. The states with the greatest reductions were in the Midwest and include Ohio (1.1 million tons reduced), Illinois, Indiana, and Missouri, each of which reduced over 500,000 tons.

Figure 5: State-by-State SO<sub>2</sub> Emissions Levels, 1990–2004



## SO<sub>2</sub> Allowance Market

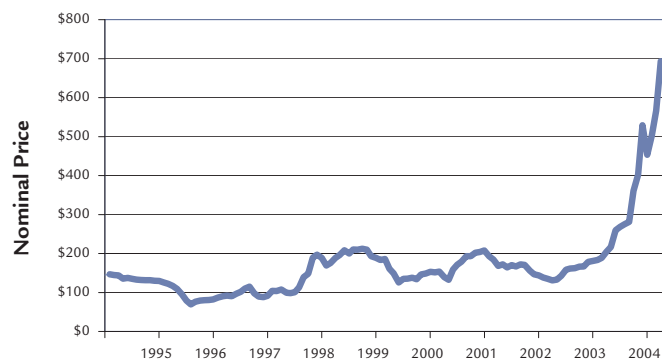
The allowance trading mechanism enables Acid Rain Program sources to pursue a variety of compliance options, while the cap on SO<sub>2</sub> emissions ensures that reductions are made and maintained over time. Some sources have opted to reduce their SO<sub>2</sub> emissions below the level of their allowance allocation in order to bank their allowances for use in future years or to sell them. Other sources have been able to postpone or reduce expenditures for control by purchasing

allowances from sources that controlled below their allowance allocation level. The allowance prices end up reflecting these flexible compliance decisions. Economists refer to this as the marginal cost of compliance—the cost of reducing the next ton of SO<sub>2</sub> emitted from the power sector.

The price of an allowance increased sharply during 2004, ending the year at about \$700 after beginning the year at about \$215 (see Figure 6). The increase primarily occurred because of EPA's Clean Air Interstate Rule (CAIR). CAIR requires further SO<sub>2</sub> reductions from sources in many eastern U.S. states beginning in 2010, and the market has already begun to factor the marginal cost of future compliance with CAIR and the future value of banked allowances today.

In 2004, nearly 20,000 private allowance transfers affecting roughly 15.3 million allowances (of past, current, and future vintages) were recorded in the EPA Allowance Tracking System (ATS). Of the allowances transferred, 7.5 million (49 percent) were transferred in economically significant

Figure 6: SO<sub>2</sub> Allowance Prices



Source: Cantor Fitzgerald

transactions (i.e., between economically unrelated parties). The majority of the allowances transferred in economically significant transactions were acquired by power companies. Figure 7 (on page 8) shows the annual volume of SO<sub>2</sub> allowances transferred under the Acid Rain Program (excluding allocations, retirements, and other transfers by EPA) since official recording of transfers began in 1994.

Figure 8 (on page 8) shows the cumulative volume of SO<sub>2</sub> allowances transferred under the Acid

Rain Program. The figure differentiates between allowances transferred in private transactions and those annually allocated and transferred to sources' accounts by EPA. Nearly 270 million allowances have been transferred since 1994, with about 68 percent of those transfers submitted by authorized account representatives. In December 2001, parties began to use a system developed by EPA to allow transfers to occur online. In 2004, account holders registered about 93 percent of all private allowance transfers through EPA's online transfer system.<sup>3</sup>

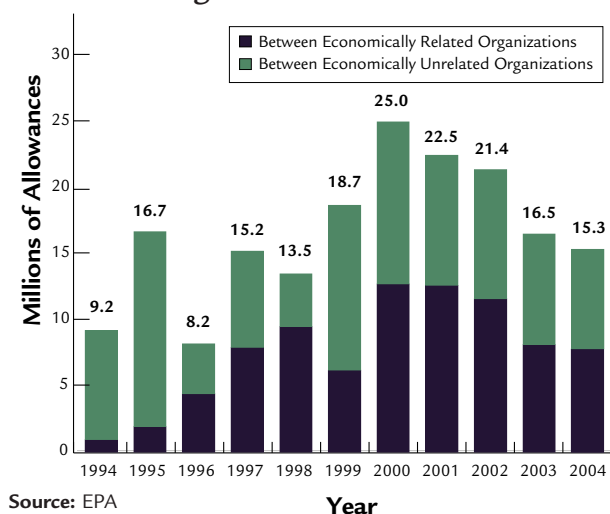
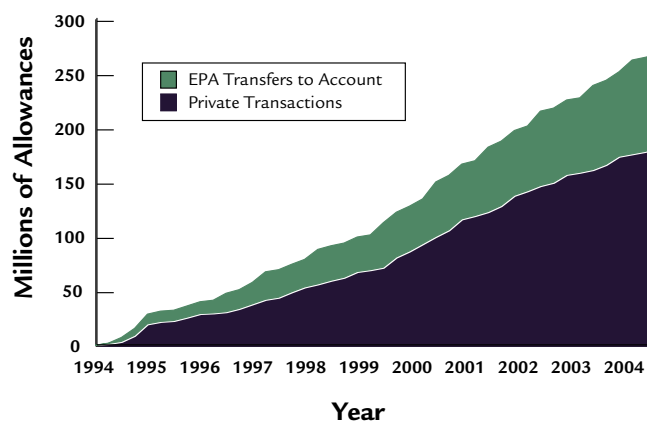
<sup>3</sup> All official allowance transactions are posted and updated daily on [www.epa.gov/airmarkets](http://www.epa.gov/airmarkets).

### Then and Now—The Evolving Market for Acid Rain Program SO<sub>2</sub> Allowances

Since the inception of the Acid Rain Program, traders in utilities and brokerages have seen considerable developments in the SO<sub>2</sub> allowance market. Changes in fuel supply, trading processes, electronic data transfer, market participants, economic and business conditions, weather, EPA regulations and settlements, and tax laws have all influenced the market's first decade. Informal discussions with market participants provided anecdotal evidence of several changes, including:

- ✧ Early trades required considerable legal advice, cost as much as \$5 per ton in brokerage fees, and took months to complete. With standardized transaction agreements and contract forms, one broker noted that transaction fees have dropped to \$0.50 per ton and trades typically take one or two weeks.
- ✧ In 1995, utilities tended to engage in simple trades to cover their needs. By 2000, energy marketers had joined in speculative trading and introduced instruments like options and vintage year swaps. In 2002, some traders observe that reaction to the dissolution of Enron temporarily reversed the trend toward a larger, more complex market. Recently, banks and hedge funds have brought back speculative trading, and two trading systems (the New York Mercantile Exchange [NYMEX] and the Chicago Climate Exchange [CCX]) have created futures markets for allowances.
- ✧ Traders note that improved access to allowance and emission data, such as through EPA's Data and Maps Web site, has provided increasingly accessible, up-to-date information, providing a firm foundation for well-informed allowance transactions.
- ✧ Initially, utilities banked allowances and prices fell based on the relatively low-cost compliance option of using low-sulfur coal from Wyoming's Powder River Basin. The additional reductions required under CAIR have already begun to influence market prices for SO<sub>2</sub> allowances.



Figure 7: SO<sub>2</sub> Allowances Transferred under the Acid Rain ProgramFigure 8: Cumulative SO<sub>2</sub> Allowances Transferred (through 2004)

## SO<sub>2</sub> Program Compliance

A total of nearly 10.3 million allowances were deducted from sources' accounts in 2004 to cover emissions. Figure 9 displays these allowance deductions, as well as the remaining banked allowances from 1995 through 2004.

As in previous years, compliance with the Acid Rain Program continues to be extraordinarily high—nearly 100 percent. In 2004, four units out of 3,391 were out of compliance. A source that

does not hold enough allowances in its unit account to cover its annual SO<sub>2</sub> emissions has “excess emissions” and must pay an automatic penalty. Title IV set a penalty of \$2,000 per ton in 1990, which has been adjusted annually for inflation; the 2004 penalty was \$2,963 per ton. The owners of the four units out of compliance in 2004 were assessed a penalty of approximately \$1.4 million for emitting 465 tons of SO<sub>2</sub> in excess of the allowances held in their accounts.

Figure 9: SO<sub>2</sub> Allowance Reconciliation Summary, 2004

Total Allowances Held (1995-2004 vintages) <sup>4</sup>		17,116,044
Unit Accounts	13,610,501	
General Accounts <sup>5</sup>	3,505,543	
Allowances Deducted for Emissions <sup>6</sup>		10,259,771
Penalty Allowance Deductions (2005 Vintage)		465
Banked Allowances		6,856,273
Unit Accounts	3,350,730	
General Accounts <sup>5</sup>	3,505,543	

Source: EPA

<sup>4</sup> As of March 1, 2004, the Allowance Transfer Deadline, the point in time at which unit accounts are frozen and after which no transfers of 1995 through 2004 allowances will be recorded. The freeze on these accounts is removed when annual reconciliation is complete. The total held in the ATS accounts equals the number of 2004 allowances allocated (see Figure 4 on page 5) plus the number of banked allowances.

<sup>5</sup> General accounts can be established in the ATS by any utility, individual, or other organization.

<sup>6</sup> Includes 212 allowances deducted from opt-in sources for reduced utilization.

## NO<sub>x</sub> Emission Reductions

Title IV of the 1990 Clean Air Act Amendments requires NO<sub>x</sub> emission reductions for certain coal-fired units. Unlike the SO<sub>2</sub> program, Congress applied rate-based emission limits based on a unit's boiler type to achieve NO<sub>x</sub> reductions (see Figure 10). The NO<sub>x</sub> emission rate is expressed as pounds per unit of heat input (lbs/mmBtu) to the boiler. Owners can meet the NO<sub>x</sub> limits for each individual unit or meet the average of groups of units.

The NO<sub>x</sub> program seeks to attain a 2 million ton annual reduction from all Acid Rain Program sources relative to the NO<sub>x</sub> emission levels that were projected to occur in 2000 (8.1 million tons) absent the Acid Rain Program. This goal was first realized in 2000, and has been met every year thereafter, including 2004. Figure 11 (on page 10) shows that NO<sub>x</sub> emissions from all Acid Rain Program sources were 3.8 million tons in 2004. This level is more than 4 million tons less than the projected level in 2000 without the Acid Rain Program, or more than double the Title IV NO<sub>x</sub> emissions reduction objective. These reductions

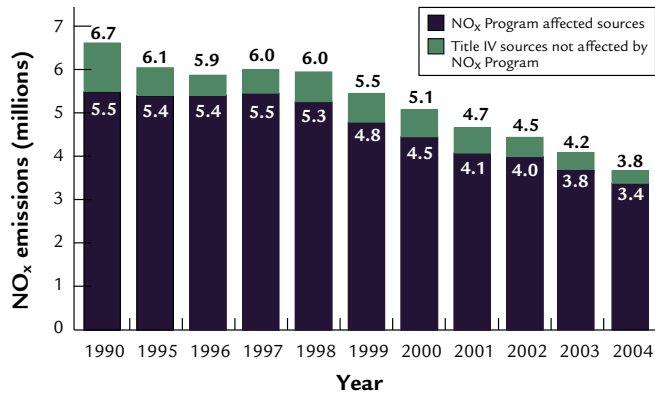
have been achieved while the amount of fuel burned to produce electricity, as measured by heat input, has increased 34 percent since 1990. While the Acid Rain Program was responsible for a large portion of these annual NO<sub>x</sub> reductions, other programs, such as the Ozone Transport Commission (OTC) NO<sub>x</sub> Budget Trading Program and the EPA's NO<sub>x</sub> State Implementation Plan (SIP) Call, both of which are seasonal, regional NO<sub>x</sub> programs, also contributed significantly to the NO<sub>x</sub> reductions achieved by emitting sources in 2004.

As with SO<sub>2</sub>, the states with the highest NO<sub>x</sub> emitting sources in 1990 tended to see the greatest power plant NO<sub>x</sub> emission reductions (see Figure 12 on page 10). The sum of reductions in the 38 states and the District of Columbia that had lower annual NO<sub>x</sub> emissions in 2004 than in 1990 was approximately 2.7 million tons, while the sum of increases in the 10 states that had higher annual NO<sub>x</sub> emissions in 2004 than in 1990 was much smaller, less than 63,000 tons. Eight of the 11 states with NO<sub>x</sub> emission decreases of more than 100,000 tons were in the Ohio River Basin.

Figure 10: Number of NO<sub>x</sub>-Affected Title IV Units by Boiler Type

Coal-Fired Boiler Type	Title IV Standard Emission Limit (lb/mmBtu)	Number of Units
Phase I Group 1 Tangentially-fired	0.45	132
Phase I Group 1 Dry Bottom, Wall-fired	0.50	116
Phase II Group 1 Tangentially-fired	0.40	301
Phase II Group 1 Dry Bottom, Wall-fired	0.46	298
Cell Burners	0.68	37
Cyclones >155 MW	0.86	54
Wet Bottom >65 MW	0.84	24
Vertically-fired	0.80	27
<b>Total</b>		<b>989</b>

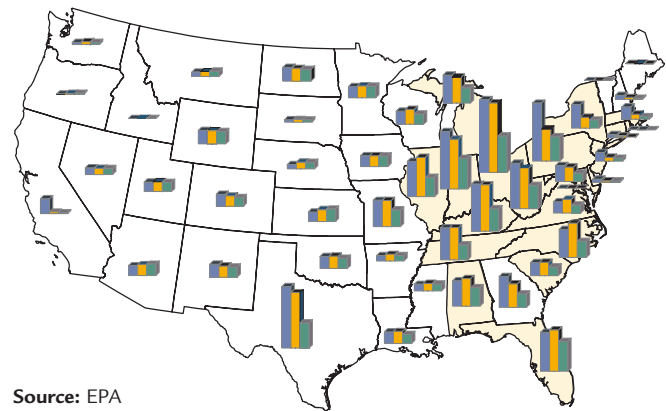
Figure 11: NO<sub>x</sub> Emission Trends for Acid Rain Program Units 1990 to 2004



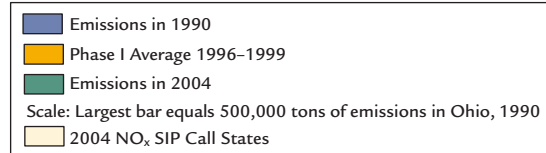
Source: EPA

**Note:** The sharp decline in emissions observed since 1999 reflects not only the Phase II Acid Rain Program NO<sub>x</sub> requirements, but also seasonal reductions from May to September that began in nine northeastern U.S. states and D.C. in 1999 and 11 additional states under the NO<sub>x</sub> SIP Call beginning in 2004 (see the shaded states in Figure 12). New Hampshire participated in the northeastern U.S. program through 2002, but does not participate in the NO<sub>x</sub> SIP Call program.

Figure 12: State-by-State NO<sub>x</sub> Emission Levels for All Acid Rain Program Sources 1990 to 2004



Source: EPA



## Sources Achieved 100 Percent NO<sub>x</sub> Compliance in 2004, Using a Variety of NO<sub>x</sub> Compliance Plan Options

**Standard Limitation.** A unit with a standard limit meets the applicable individual NO<sub>x</sub> limit prescribed for its boiler type under 40 CFR 76.5, 76.6, or 76.7 (116 units used this option in 2004).

**Early Election.** Phase II Group 1 NO<sub>x</sub> affected units could meet a less stringent Phase I NO<sub>x</sub> limit beginning in 1997, three years before 2000, when they would normally become subject to an Acid Rain NO<sub>x</sub> limit. In return for accepting a NO<sub>x</sub> limit three years earlier than would normally be required, an early election unit does not become subject to the more stringent Phase II NO<sub>x</sub> limit until 2008 (273 units used this option in 2004).

**Emissions Averaging.** Many companies have their units meet their NO<sub>x</sub> emission reduction requirements by choosing to become subject to a group NO<sub>x</sub> limit, rather than by meeting individual NO<sub>x</sub> limits for each unit. The group limit is established at the end of each calendar year, and the group rate for the units must be less than or equal to the Btu-weighted group rate units would have had if each had emitted at their standard limit rate (620 units used this option in 2004).

**Alternative Emission Limitation (AEL).** A utility can petition for a less stringent AEL if it properly installs and operates the NO<sub>x</sub> emissions reduction technology prescribed for that boiler, but is unable to meet its standard limit. EPA determines whether an AEL is warranted based on analyses of emission data and information about the NO<sub>x</sub> control equipment (21 units used this option in 2004).

**Note:** Unit counts exclude units with a Retired Unit Exemption. Also, some units used multiple compliance options. Ten units under an emissions averaging plan also were covered by an AEL, and 31 units were under both an emissions averaging and early election plan.

## Then and Now: Advances in NO<sub>x</sub> Control

Since Congress enacted the Acid Rain Program in 1990, the electric power industry has made significant innovations and advances in reducing NO<sub>x</sub> emissions. The Acid Rain Program served as the impetus for some of these changes, but other programs, such as EPA's 1998 NO<sub>x</sub> SIP Call, have led to many of the advances. Some highlights include:

- ❖ **Boiler optimization.** Boiler optimization modeling systems manipulate multiple control parameters simultaneously in order to meet a unit's specific operational needs and emission reduction goals. Sources have shown that optimization is capable of reducing NO<sub>x</sub> emissions by between 13 and 24 percent, while maintaining or increasing boiler efficiency and significantly reducing fuel costs. In addition, optimization and NO<sub>x</sub> reductions in units with selective catalytic reduction systems (SCRs) can lower ammonia usage and extend catalyst life, resulting in lower operational costs.
- ❖ **Advanced combustion controls.** The design of low-NO<sub>x</sub> burner (LNB) emission control technologies has improved significantly since 1995, leading to lower NO<sub>x</sub> emission rates. The average NO<sub>x</sub> emission rate from boilers utilizing LNB technology in 2003 was between 35 and 60 percent lower than the average emission rate from LNB units in 1995.
- ❖ **Application of SCR to coal-fired boilers.** In 1995, there were significant doubts in the electric power industry about the application of SCR technology to U.S. coal-fired boilers, particularly because of high-sulfur fuel interfering with catalyst performance. With the reductions required under the 1998 NO<sub>x</sub> SIP Call, the industry has moved to resolve those issues, and by the end of 2004, over 130 coal-fired boilers in the United States had installed SCRs (primarily for NO<sub>x</sub> SIP Call compliance) and were able to achieve sustained emission rates as low as 0.03 lbs/mmBtu.

## Emissions Monitoring and Reporting

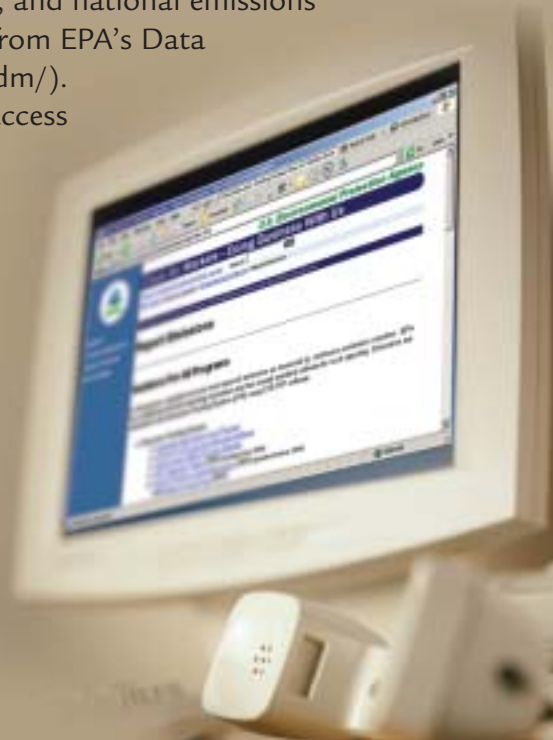
The Acid Rain Program requires program participants to measure, record, and report emissions using continuous emission monitoring systems (CEMS) or an approved alternative measurement method. Since the program's inception in 1995, emissions have been continuously monitored and reported by sources, verified and recorded by EPA, and provided to the public through EPA's Web site. All affected sources report hourly emission data in electronic reports (submitted quarterly), and EPA conducts automated software audits that perform rigorous checks to ensure the

completeness, high quality, and integrity of the emission data. CEMS and approved alternatives are a cornerstone of the Acid Rain Program's accountability and transparency.

The emission monitoring requirements are found in 40 CFR Part 75. In addition to the Acid Rain Program, these provisions are also required for participation in the NO<sub>x</sub> Budget Trading Program, a NO<sub>x</sub> trading program used by many eastern states in response to EPA's 1998 NO<sub>x</sub> SIP Call, and will be used in the future to implement two new rules promulgated in 2005, CAIR and CAMR.

## Advances in Emissions and Allowance Transfer Reporting

- ✧ At the start of the Acid Rain Program, sources used a combination of paper forms and floppy disks. The program required submission of emission data on floppy disks, and other source information management activities, such as monitoring plan information, allowance transfer, and certificates of representation, were all originally addressed through paper forms.
- ✧ This approach required manual review and entry for paper submissions and individual file uploads for emission data. EPA feedback on submission issues involved individual letters to sources.
- ✧ Over time, EPA moved to electronic transfer of information:
  - Monitoring plans moved primarily to electronic submission as part of the quarterly reporting process. EPA released Monitoring Data Checking (MDC) software that allowed sources to enter, analyze, print, and export electronic monitoring plans. EPA uses MDC to conduct electronic audits of submittals and provide automated feedback to sources.
  - Through the Emissions Tracking System file transfer protocol (ETS-FTP), EPA moved to direct, secure electronic transfer of quarterly reports from a source's computer to EPA's mainframe system. EPA then was able to provide instant automated feedback to sources concerning issues with submitted emission data.
  - In 2001, an Online Allowance Tracking System enabled direct Internet recording for allowance trades.
- ✧ Now the Online Allowance Tracking System is integrated with an enhanced Clean Air Markets Division Business System (CBS) and offers online allowance trading as well as online options for other account and source information management activities.
- ✧ Public access to information has advanced dramatically. Early access was through paper compliance reports, and then individual unit data files that were difficult to use. Now, detailed unit, facility, state, and national emissions and other data for ARP sources is available from EPA's Data and Maps Web site (<http://cfpub.epa.gov/gdm/>). This site provides a combination of easy to access "quick" reports and highly flexible, custom "query" reports.
- ✧ EPA is in the process of designing a comprehensive Emissions Collection and Monitoring Plan System (ECMPS) to cover all aspects of secure reporting of emissions, monitoring plans, and quality assurance data.



## Status and Trends in Air Quality, Acid Deposition, and Ecological Effects

The emission reductions achieved under the Acid Rain Program have led to important environmental and public health benefits. These include improvements in air quality with significant benefits to human health, reductions in acid deposition, the beginnings of recovery from acidifi-

cation of fresh water lakes and streams, improvements in visibility, and reduced risk to forests, materials, and structures. Figure 13 shows the regional changes in many of these key variables linked to the Acid Rain Program's SO<sub>2</sub> and NO<sub>x</sub> emission reductions.

**Figure 13: Regional Changes in Air Quality and Deposition of Sulfur and Nitrogen (1989 to 1991 versus 2002 to 2004)**

Measurement	Unit	Region	Average*		Percent Change**
			1989–1991	2002–2004	
Wet sulfate deposition	kg/ha	Mid-Atlantic	27	20	-24
		Midwest	23	16	-32
		Northeast	23	14	-36
		Southeast	18	15	-19
Wet sulfate concentration	mg/L	Mid-Atlantic	2.4	1.6	-33
		Midwest	2.3	1.5	-32
		Northeast	1.9	1.2	-35
		Southeast	1.3	1.0	-23
Ambient sulfur dioxide concentration	µg/m <sup>3</sup>	Mid-Atlantic	13	7.9	-37
		Midwest	10	5.7	-46
		Northeast	6.8	3.1	-54
		Southeast	5.2	3.2	-39
Ambient sulfate concentration	µg/m <sup>3</sup>	Mid-Atlantic	6.4	4.6	-27
		Midwest	5.6	3.8	-33
		Northeast	3.9	2.6	-33
		Southeast	5.4	4.0	-26
Wet inorganic nitrogen deposition	kg/ha	Mid-Atlantic	5.9	5.5	-8
		Midwest	6.0	5.7	-4
		Northeast	5.3	4.5	-16
		Southeast	4.3	4.3	0
Wet nitrate concentration	mg/L	Mid-Atlantic	1.5	1.1	-28
		Midwest	1.4	1.3	-12
		Northeast	1.3	1.0	-22
		Southeast	0.8	0.7	-9
Ambient nitrate concentration	µg/m <sup>3</sup>	Mid-Atlantic	0.9	0.9	-3
		Midwest	2.1	1.8	-11
		Northeast	0.4	0.5	27
		Southeast	0.6	0.7	14
Total ambient nitrate concentration (nitrate + nitric acid)	µg/m <sup>3</sup>	Mid-Atlantic	3.5	2.9	-15
		Midwest	4.0	3.5	-13
		Northeast	2.0	1.8	-7
		Southeast	2.2	2.0	-6

Source: CASTNET and NADP/NTN

\*Measurement data are reported as two significant digits and reflect an updated rounding convention from last year's report.

\*\*Percent change is estimated from raw measurement data, not rounded; some of the measurement data used to calculate percentages may be at or below detection limits.

# Understanding the Monitoring Networks

To evaluate the impact of emission reductions on the environment, scientists and policymakers use data collected from long-term national monitoring networks such as the Clean Air Status and Trends Network (CASTNET) and the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). These complementary, long-term monitoring networks provide information on a variety of indicators necessary for tracking temporal and spatial trends in regional air quality and acid deposition (see Figure 14).

CASTNET provides atmospheric data on the dry deposition component of total acid deposition, ground-level ozone, and other forms of atmospheric pollution. Established in 1987, CASTNET now consists of more than 80 sites across the United States. EPA's Office of Air and Radiation operates most of the monitoring stations; the National Park Service (NPS) funds and operates approximately 30 stations in cooperation with EPA. Many CASTNET sites are approaching a continuous 20-year data record, reflecting EPA's commitment to long-term environmental monitoring. Public access to

CASTNET data are available through the Clean Air Markets Web site at [www.epa.gov/airmarkets](http://www.epa.gov/airmarkets).

NADP/NTN is a nationwide, long-term network tracking the chemistry of precipitation. NADP/NTN offers data on hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations. The network is a cooperative effort involving many groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, EPA, NPS, the National Oceanic and Atmospheric Administration (NOAA), and other governmental and private entities. NADP/NTN has grown from 22 stations at the end of 1978 to more than 250 sites spanning the continental United States, Alaska, Puerto Rico, and the Virgin Islands.

While CASTNET provides some ambient air quality data, EPA also uses data from other ambient monitoring networks, including the State and Local Air Monitoring Stations and National Air Monitoring Stations (SLAMS/NAMS). These networks are used to document National Ambient Air Quality Standards (NAAQS) attainment and show trends in ambient air quality over time.

**Figure 14: Air Quality and Acid Deposition Measurements**

Chemicals		Why are these measured by the networks?
SO <sub>2</sub>	Sulfur Dioxide	Indicator of ambient air quality; measured in dry monitoring networks; major precursor to acid deposition
SO <sub>4</sub> <sup>2-</sup>	Ionic Sulfates, Particulate Sulfates	Indicators of ambient air quality and sulfur deposition; regional transport; correlated with sulfur dioxide emissions; measured in wet and dry monitoring networks
NO <sub>3</sub> <sup>-</sup>	Ionic Nitrates, Particulate Nitrates	Indicators of ambient air quality and nitrogen deposition; correlated with NO <sub>x</sub> emissions; measured in wet and dry monitoring networks
HNO <sub>3</sub>	Nitric Acid	Strong acidic compound; main component of dry nitrogen deposition; measured in dry monitoring networks
NH <sub>4</sub> <sup>+</sup>	Ionic Ammonium, Particulate Ammonium	Indicators of ambient air quality and nitrogen deposition; associated with production of fine particles; aerosol ammonium is associated with sulfate ion; can play a role neutralizing atmospheric acidic species; measured in wet and dry monitoring networks
H <sup>+</sup>	Ionic Hydrogen	Indicator of acidity in precipitation; measured in wet deposition monitoring networks
Ca <sub>2</sub> <sup>+</sup> Mg <sub>2</sub> <sup>+</sup> K <sup>+</sup> Na <sup>+</sup>	Calcium Magnesium Potassium Sodium	These base cations are indicators of the ability to neutralize acids in precipitation; also play an important role in plant nutrition and soil productivity

## Air Quality

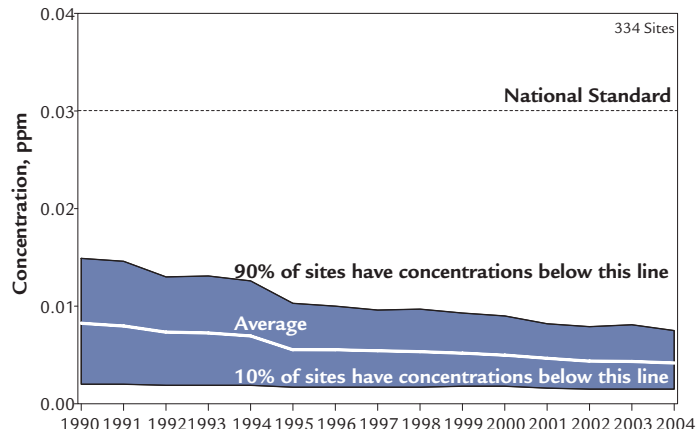
Data collected from monitoring networks show that the decline in SO<sub>2</sub> emissions from the power industry has improved air quality.<sup>7</sup> Based on EPA's latest air emissions trends data located at [www.epa.gov/airtrends/index.html](http://www.epa.gov/airtrends/index.html), the national composite average of SO<sub>2</sub> annual mean ambient concentrations decreased 49 percent between 1990 and 2004 as shown in Figure 15. The largest single-year reduction (21 percent) occurred in the first year of the Acid Rain Program, between 1994 and 1995.

These trends are consistent with the ambient trends observed in the CASTNET network. During the late 1990s, following implementation of Phase I of the Acid Rain Program, dramatic regional improvements in SO<sub>2</sub> and ambient sulfate concentrations were observed at CASTNET sites throughout the eastern United States, due to the large reductions in SO<sub>2</sub> emissions from Acid Rain Program sources. Analyses of regional monitoring data from CASTNET show the geographic pattern of SO<sub>2</sub> and airborne sulfate in the eastern United States. Three-year mean annual concentrations of SO<sub>2</sub> and sulfate from CASTNET long-term monitoring sites are compared from 1989 through 1991 and 2002 through 2004 in both tabular form and graphically in maps (see Figure 13 on page 13 and Figures 16a through 17b on page 16).

The map in Figure 16a shows that from 1989 through 1991, prior to implementation of Phase I of the Acid Rain Program, the highest ambient concentrations of SO<sub>2</sub> in the East were observed in western Pennsylvania and along the Ohio River Valley. Figure 16b indicates a significant decline in those concentrations in nearly all affected areas.

Before the Acid Rain Program, in 1989 through 1991, the highest ambient sulfate concentrations, greater than 7 µg/m<sup>3</sup>, were observed in western Pennsylvania, along the Ohio River Valley, and in northern Alabama. Most of the eastern United States experienced annual ambient sulfate concentrations greater than 5 µg/m<sup>3</sup>. Like SO<sub>2</sub>

**Figure 15: SO<sub>2</sub> Air Quality, 1990–2004**  
(Based on Annual Arithmetic Average)



Source: EPA air emission trends, [www.epa.gov/airtrends/2005/econ-emissions.html](http://www.epa.gov/airtrends/2005/econ-emissions.html)

concentrations, ambient sulfate concentrations have decreased since the program was implemented, with average concentrations decreasing approximately 30 percent in all regions of the East. Both the size of the affected region and magnitude of the highest concentrations have dramatically declined, with the largest decreases observed along the Ohio River Valley (see Figures 17a and 17b).

Although the Acid Rain Program has met its NO<sub>x</sub> reduction targets, emissions from other sources (such as motor vehicles and agriculture) have led to increased ambient nitrate concentration in some areas of the country (see Figure 13 on page 13). NO<sub>x</sub> levels in some areas can also be affected by emissions transported via air currents over wide regions.<sup>8</sup> In 2004, reduced NO<sub>x</sub> emissions from power plants under the NO<sub>x</sub> Budget Trading Program led to more significant region-specific improvements in some indicators than have been seen in previous years. For instance, total annual mean ambient nitrate concentrations (nitric acid plus particulate nitrate) for 2002 through 2004 have decreased in the Mid-Atlantic and Midwest by about 15 percent from the annual mean concentration in 1989 through 1991 (see Figures 18a and 18b on page 17). While these improvements may be partly attributed to added NO<sub>x</sub> controls installed for compliance with the NO<sub>x</sub> SIP Call, the findings at this time are not conclusive.

<sup>7</sup> It should be noted that there has not been a violation of the SO<sub>2</sub> standard at any of the monitoring sites since 2000.

<sup>8</sup> See the EPA Office of Transportation and Air Quality Web site at [www.epa.gov/otaq](http://www.epa.gov/otaq) for information on recent rules to reduce NO<sub>x</sub> emissions from mobile sources. Additional NO<sub>x</sub> reductions are occurring as a result of the NO<sub>x</sub> Budget Trading Program. See EPA's August 2005 report, *Evaluating Ozone Control Programs in the Eastern United States: Focus on the NO<sub>x</sub> Budget Trading Program, 2004*, at [www.epa.gov/airtrends/2005/ozonenbp.pdf](http://www.epa.gov/airtrends/2005/ozonenbp.pdf), which discusses these NO<sub>x</sub> reduction efforts.

Figure 16a: Annual Mean Ambient Sulfur Dioxide Concentration, 1989 through 1991

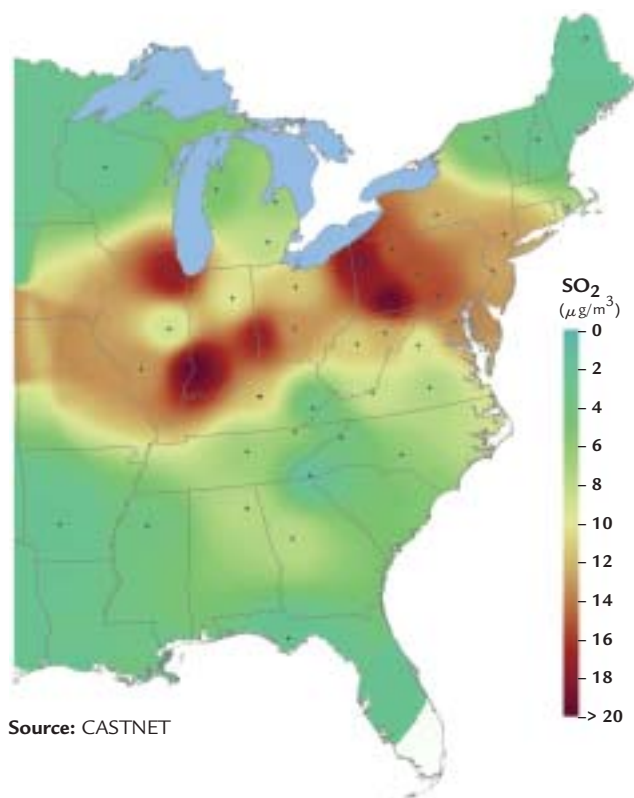


Figure 16b: Annual Mean Ambient Sulfur Dioxide Concentration, 2002 through 2004

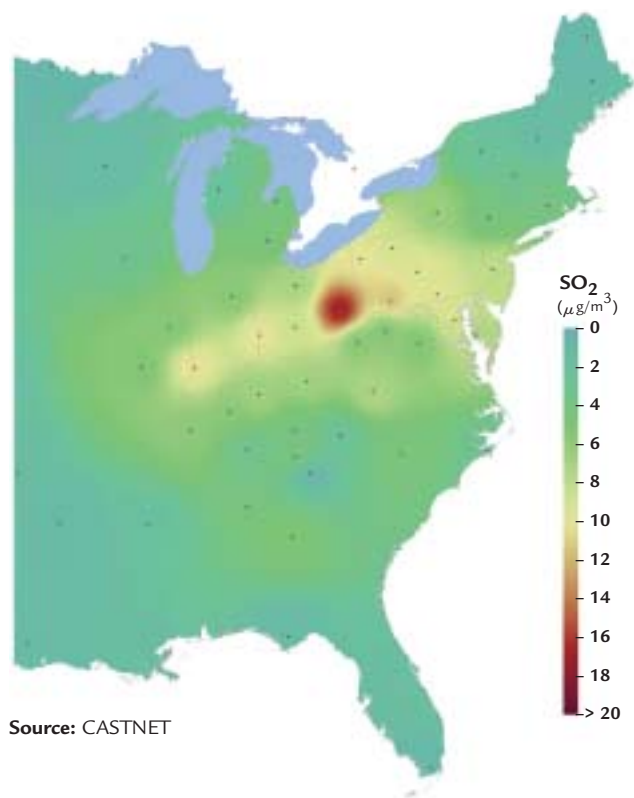


Figure 17a: Annual Mean Ambient Sulfate Concentration, 1989 through 1991

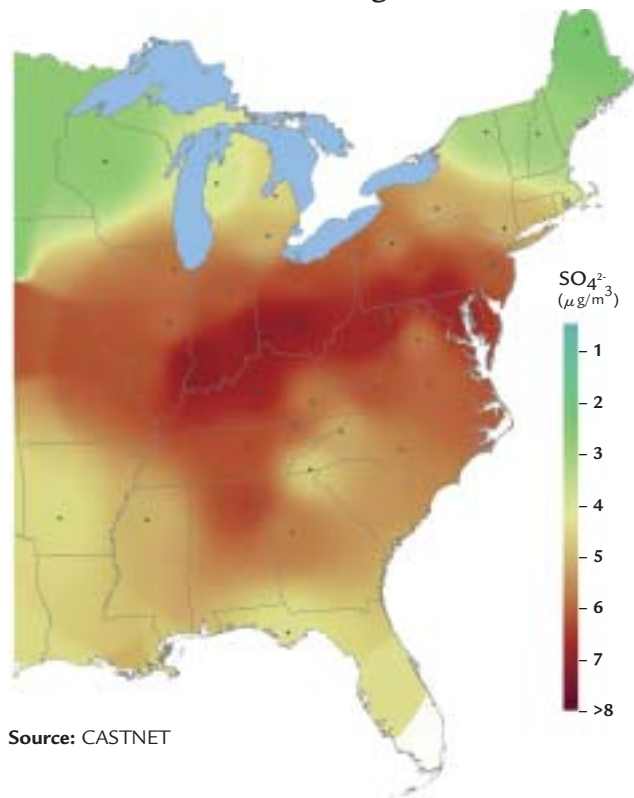


Figure 17b: Annual Mean Ambient Sulfate Concentration, 2002 through 2004

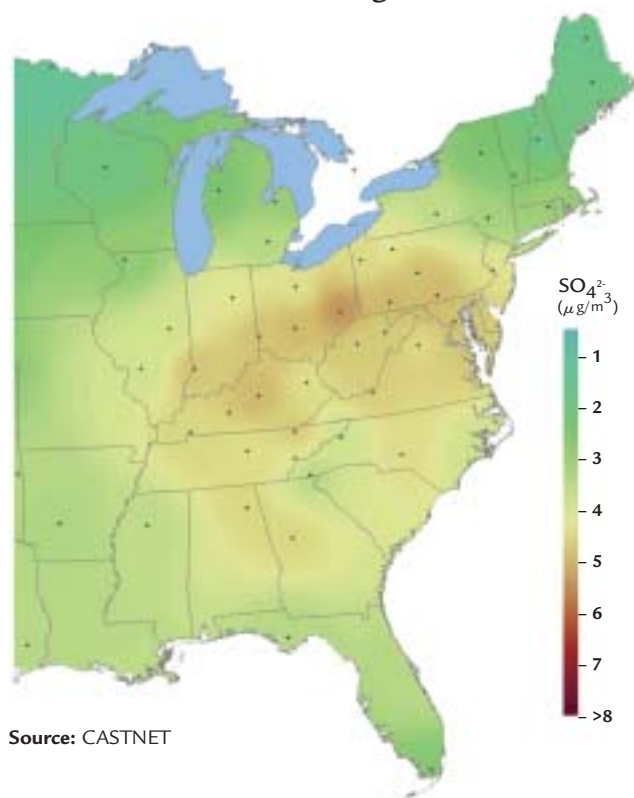


Figure 18a: Annual Mean Total Ambient Nitrate Concentration, 1989 through 1991

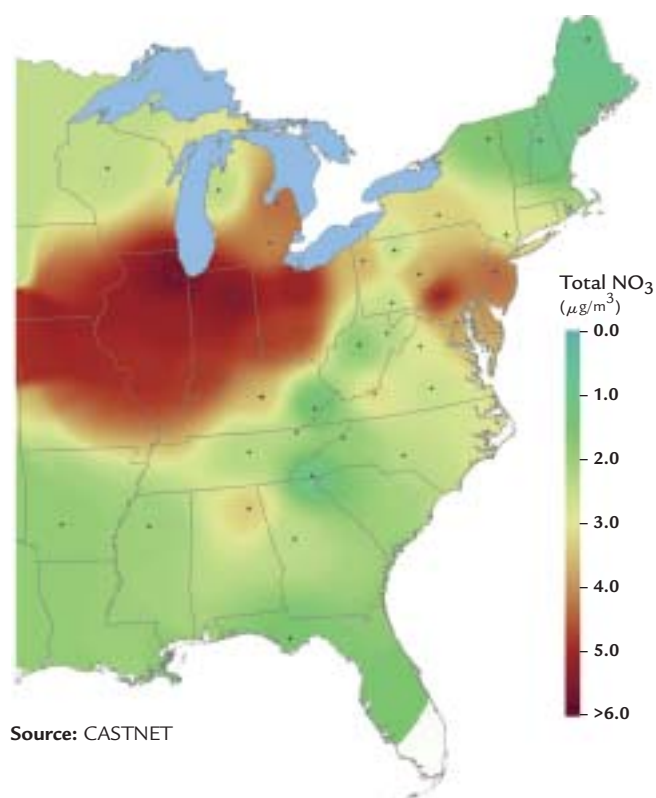
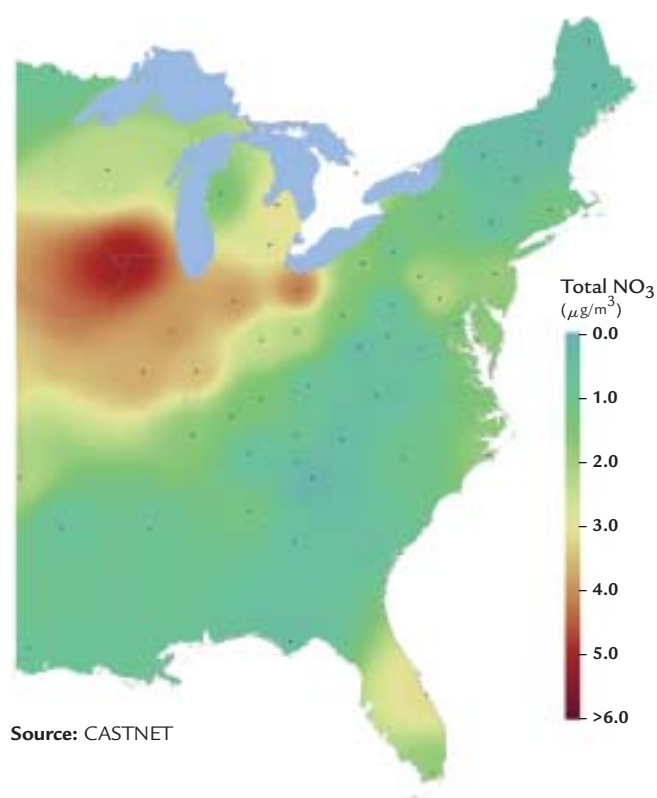


Figure 18b: Annual Mean Total Ambient Nitrate Concentration, 2002 through 2004



The CASTNET maps in this report represent ambient concentrations for the eastern United States only. During the early years of CASTNET (1989 to 1991), monitoring coverage was limited to the East with only a handful of sites in the West, which were located primarily in National Park Service-Class I areas. Today, EPA, together with its partners such as NPS, has added many sites to the network, which now consists of more than 80 sites across the country.

## Acid Deposition

NADP/NTN monitoring data show significant improvements in some deposition indicators. For example, wet sulfate deposition—sulfate that falls to the earth through rain, snow, and fog—has decreased since the Acid Rain Program was implemented with some of the greatest reductions occurring in the Mid-Appalachian region, including Maryland, New York, West Virginia, Virginia, and most of Pennsylvania. Wet sulfate deposition decreased throughout the early 1990s in much of the Ohio River Valley and northeastern United States. Other less dramatic reductions have been observed across much of New England, portions of the southern Appalachian Mountains and in some areas of the Midwest. Average decreases in wet deposition of sulfate range from 36 percent in the

Northeast to 19 percent in the Southeast (see Figure 13 on page 13, and Figures 19a, and 19b on page 18).

Since 1991, wet sulfate concentrations have decreased significantly as well, with average levels decreasing 35 percent in the Northeast, 33 percent in the Mid-Atlantic, and 32 percent in the Midwest. A strong correlation between large scale  $\text{SO}_2$  emission reductions and large reductions in sulfate concentrations in precipitation has been noted in the Northeast, one of the areas most affected by acid deposition.

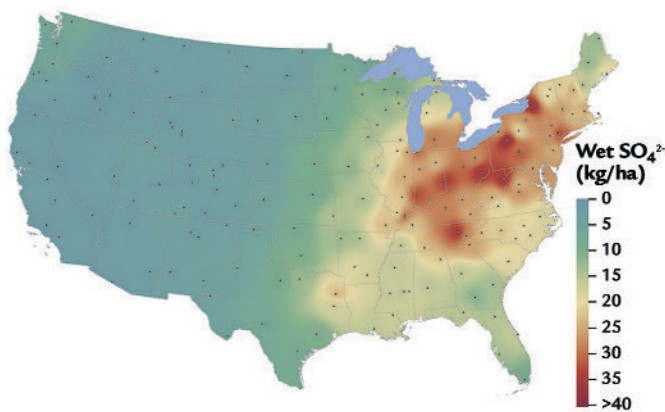
A principal reason for reduced concentrations of sulfate in precipitation in the Northeast is a reduction in the long-range transport of sulfate

from emission sources located in the Ohio River Valley. The reductions in sulfate documented in the Northeast, particularly across New England and portions of New York, were also affected by  $\text{SO}_2$  emission reductions in eastern Canada. NADP data indicate that similar reductions in precipitation acidity, expressed as hydrogen ion ( $\text{H}^+$ ) concentrations, occurred concurrently with sulfate reductions, but have not decreased as dramatically due to a simultaneous decline in acid-neutralizing base cations, which act to buffer acidity.

Reductions in nitrogen deposition recorded since the early 1990s have been less dramatic than

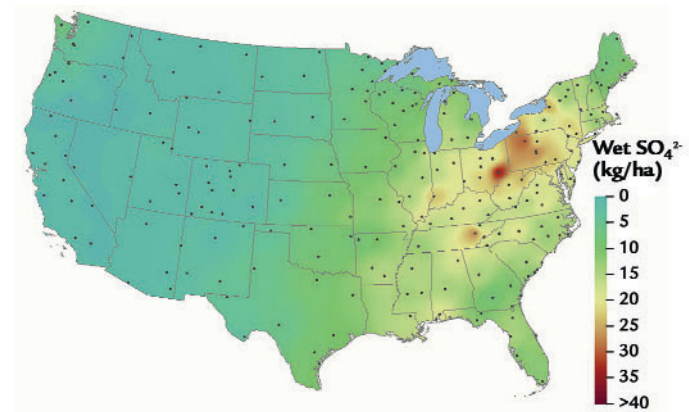
those for sulfur. As noted earlier, emission trends from source categories other than Acid Rain Program sources significantly affect air concentrations and deposition of nitrogen. Inorganic nitrogen deposition decreased modestly in the Mid-Atlantic and Northeast (averaging 8 to 16 percent) but remained virtually unchanged in other regions (see Figures 20a and 20b). Wet nitrate concentrations have dropped significantly in the Mid-Atlantic and Northeast regions, but are not tied to precipitation (see Figure 13 on page 13). Modest reductions of about 10 percent have occurred in the Midwest and Southeast.

**Figure 19a: Annual Mean Wet Sulfate Deposition 1989 through 1991**



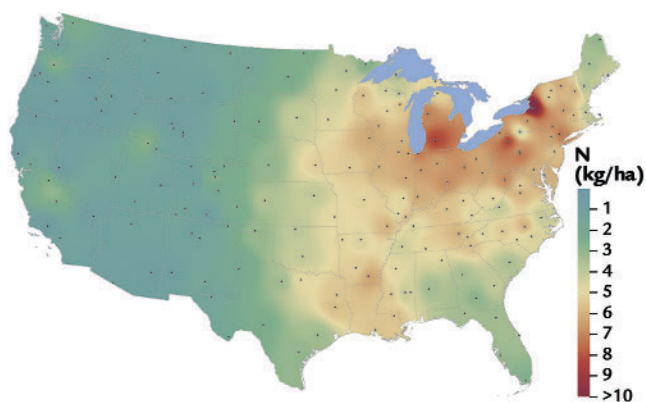
Source: National Atmospheric Deposition Program

**Figure 19b: Annual Mean Wet Sulfate Deposition 2002 through 2004**



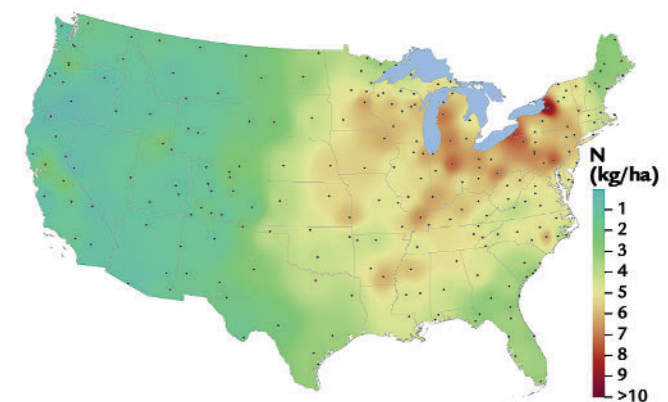
Source: National Atmospheric Deposition Program

**Figure 20a: Annual Mean Wet Inorganic Nitrogen Deposition 1989 through 1991**



Source: National Atmospheric Deposition Program

**Figure 20b: Annual Mean Wet Inorganic Nitrogen Deposition 2002 through 2004**



Source: National Atmospheric Deposition Program

Note: Dots on maps represent monitoring sites

## Recovery of Acidified Lakes and Streams

Over the past 25 years, the effect of acid deposition on lakes and streams has been the focus of much research, particularly in areas of the eastern United States that are both sensitive to acid deposition and receiving significant levels over time. These areas encompass New England, the Adirondack Mountains, the northern Appalachian Plateau (including the Catskill and Pocono Mountains), and the Blue Ridge region (including streams in western Virginia) (see Figure 21). As shown in the deposition maps, above, implementation of Title IV has resulted in decreased sulfate deposition across the East, while changes in nitrate deposition have been small. Recent studies provide data regarding the response of lakes and streams to changes in emissions.

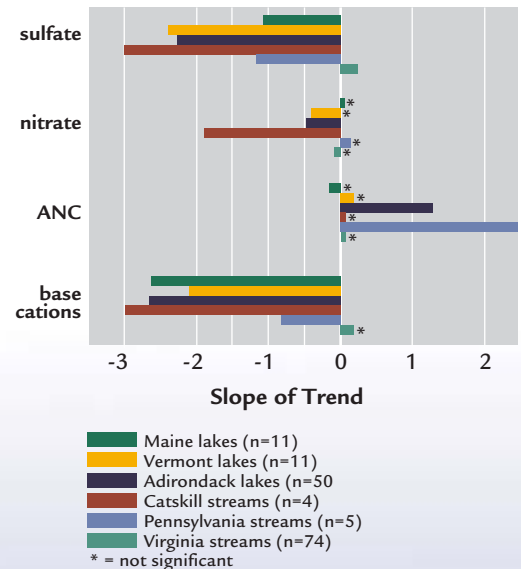
A 2005 study<sup>9</sup> examined alterations in lake water chemistry as a result of deposition changes at 130 monitoring sites between 1984 and 2001. The sites were chosen to allow generalizations regarding the effects of decreases in acidic deposition in 3,666 lakes throughout the entire northeastern United

### Improvements in Surface Water

EPA's Temporally Integrated Monitoring of Ecosystems (TIME) and Long-Term Monitoring (LTM) programs (described in a text box on page 20) provide information on the chemistry of lakes and streams, which allows researchers to understand how water bodies are responding to changes in emissions. The data presented here show regional trends in acidification from 1990 to 2000 in areas of the eastern United States. For each lake or stream in the network, measurements of various indicators of recovery from acidification were taken. These measurements were plotted against time, and trends for the given lake or stream during the 10-year period were then calculated as the change in each of the measurements per year (e.g., change in concentration of sulfate per year). Using the trends calculated for each water body, median regional changes were determined for each of the measures of recovery. A negative value of the "slope of the trend" means that the measure has been declining in the region, while a positive value means it has been increasing. The greater the value of the trend, the

greater the yearly change in the measurement. Movement toward recovery is indicated by positive trends in acid neutralizing capacity (ANC) and negative trends in sulfate, nitrate, hydrogen ion, and aluminum. Negative trends in base cations can balance out the decreasing trends in sulfate and nitrate and hinder improvements in ANC.

Figure 21: Regional Trends in Lake and Stream Acidification, 1990-2000



**Source:** Stoddard, J.L., Kahl, J.S., Deviney, F.A., DeWalle, D.R., Driscoll, C.T., Herlihy, A.T., Kellogg, J.H., Murdoch, P.S., Webb, J.R., and Webster, K.E. (2003) *Response of surface water chemistry to the Clean Air Act Amendments of 1990*. EPA620-R-03-001. Washington, DC: U.S. Environmental Protection Agency.

<sup>9</sup> Warby, R.A.F., Johnson, C.E., and Driscoll, C.T. *Chemical recovery of surface waters across the northeastern United States from reduced inputs of acidic deposition: 1984-2001*. Syracuse, New York: Syracuse University.

## Long-Term Environmental Monitoring at EPA

EPA's Temporally Integrated Monitoring of Ecosystems (TIME) and Long-Term Monitoring (LTM) programs are designed to detect trends in the chemistry of regional populations of lakes or streams and to determine whether emission reductions have had the intended effect of reducing acidification.

These programs monitor a total of 145 lakes and 147 streams, representing all of the major acid-sensitive regions of the northern and eastern United States, including the upper Midwest, New England, Adirondack Mountains, northern Appalachian Plateau (including the Catskill Mountains), and the Blue Ridge Mountain region of Virginia. TIME/LTM measure a variety of important chemical characteristics, including acid neutralizing capacity (ANC), pH, sulfate, nitrate, major cations (e.g., calcium and magnesium), and aluminum. While the representativeness of the TIME/LTM network is somewhat limited, the TIME program provides a coherent individual regional dataset for this kind of analysis. In addition, the U.S. Geological Survey (USGS) has been measuring surface water quality at several research watersheds throughout the United States, where sample collection during hydrologic events and ancillary data on other watershed characteristics have been used to assess the watershed processes controlling acidification of surface waters.



States. The overall decrease in acidic deposition has resulted in some chemical recovery of surface waters, with increases in pH and ANC and decreases in strong acidic anions and inorganic monomeric aluminum. The 2005 study reports a systematic increase in ANC in lakes across the Northeast:

- Approximately 4.5 percent of lakes in the Northeast are chronically acidic ( $\text{ANC} < 0$ ), down from 6 percent in 1984.
- Eleven percent of lakes have low ANC levels ( $\text{ANC} 0\text{--}25$ ), down from 13 percent in 1984.
- Approximately 84.5 percent of lakes have moderate ANC levels ( $\text{ANC} > 25$ ), up from 81 percent in 1984.
- Despite region-wide increases in ANC in recent years, waters with  $\text{ANC} < 50$  remain sensitive to acidic deposition and could experience adverse biological response associated with episodic acidification. It is also important to note that estimates of the numbers of acidic and low-ANC lakes would increase if smaller lakes ( $< 4$  hectares) were considered.

Another recent study<sup>10</sup> focused specifically on a subset of northeastern lakes in the Adirondack Mountain region from 1992 to 2004. This study found trends similar to those for the northeastern region for 48 lakes included in the Adirondack Long-Term Monitoring Program:

- Forty-seven of 48 sites showed significant decreases in combined concentrations of sulfate and nitrate.
- The declines in sulfate concentrations have not been uniform over the 1992 to 2004 period, with greater declines in the 1990s and a leveling of sulfate concentrations over the last five years as emissions of  $\text{SO}_2$  and wet sulfate deposition have leveled off.
- Twenty-seven of the 48 lakes showed significant decreases in nitrate concentrations, with only three exhibiting increases. It is unclear why nitrate concentrations have declined at

<sup>10</sup> Driscoll, C.T., Driscoll, K.M., Roy, K.M., and Dukett, J. Changes in the chemistry of lakes in the Adirondack region of New York following declines in acidic deposition. *Environmental Geochemistry and Health*. (in review)

certain locations while there has not been any appreciable change in emissions of  $\text{NO}_x$  or atmospheric nitrate deposition.

- Thirty-seven of the 48 lakes showed significant trends of increasing ANC, attributed to decreasing concentrations of both  $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$ . Rates of ANC increase are relatively slow, however, and, at current rates, it will be several decades before full chemical recovery is approached.

Recent studies<sup>11</sup> used data on Shenandoah National Park watershed ecosystems to determine regional trends for streams in western Virginia:

- An analysis using data from 1988 to 2003 showed that sulfate concentrations were generally not decreasing and, in many cases, were increasing. Decreases in nitrate concentrations were generally greater than those for sulfate and could account for much of the observed increase in ANC concentrations. Changes in nitrate concentrations were attributed to the gypsy moth defoliation of watersheds during the late 1980s and early 1990s; the same conclusion was reached in a 1998 to 2001 analysis. Thus, the 1988 to 2003 trend analysis provides less evidence for recovery from acidification due to atmospheric deposition.

Implementation of the Acid Rain Program has substantially reduced emissions of  $\text{SO}_2$  and  $\text{NO}_x$  from power generation sources. However, the National Acid Precitation Assessment Program (NAPAP) 2005 Report to Congress,<sup>12</sup> recent modeling, and many published articles indicate that  $\text{SO}_2$  and  $\text{NO}_x$  emission reductions achieved under Title IV are insufficient to achieve full recovery or to prevent further acidification in some regions. The studies described above support that conclusion, showing that environmental improvements have been slow in many sensitive areas, and signs of recovery still are not evident in some areas. The NAPAP Report to Congress concluded that additional  $\text{SO}_2$  and  $\text{NO}_x$  emission reductions from power plants and other sources are necessary to decrease deposition and further reduce the number of acidic lakes and streams in many regions of the United States. Additional emission reductions will be achieved through implementation of existing or future regulations to address transport of ozone and fine particles and mercury deposition, including the  $\text{NO}_x$  SIP Call in the Eastern United States; Tier II and diesel rules affecting mobile sources; state implementation plans to achieve the ozone and fine particle National Ambient Air Quality Standards (NAAQS); and the recent rules to reduce interstate transport of fine particles and ozone, mercury, and regional haze from power plants.

## Quantifying Costs and Benefits of the Acid Rain Program

A new 2005 analysis<sup>13</sup> of the annual benefits and costs of the Acid Rain Program updates those of the NAPAP 1990 Integrated Assessment and a 1995 EPA report,<sup>14</sup> and integrates scientific knowledge that has emerged since the 1990s. An expanded list of impacts increases the program's estimated benefits, while newer implementation strategies—unforeseen in 1990—lower estimated costs. The estimated value of the program's annual benefits in the year 2010 now totals \$122 billion (2000\$). These benefits result

mostly from the prevention of health-related impacts (such as premature deaths, illnesses, and work days missed due to illness), but also include improved visibility in parks, and other recreational and ecosystem improvements. The paper indicates that these benefits stem from the substantial difference that the Acid Rain Program is expected to make in many areas meeting NAAQS by 2010 for fine particles less than 2.5 micrometers in diameter ( $\text{PM}_{2.5}$ ) and ozone standards (see Figure 22 on page 22). Notably, some

<sup>11</sup> Webb, J.R., Deviney, F.A., Jr., and Maben, S. *Shenandoah Watershed Study (SWAS) Annual Report for 2003*. University of Virginia.

Webb, J.R., Cosby, B.J., Deviney, F.A., Jr., Galloway, J.N., Maben, S.W., and Bulger, A.J. (2004) Are brook trout streams in western Virginia and Shenandoah National park recovering from acidification? *Environmental Science and Technology*, 38.

<sup>12</sup> 2005 National Acid Precitation Assessment Program Report to Congress, [www.al.noaa.gov/AQRS/reports/napapreport05.pdf](http://www.al.noaa.gov/AQRS/reports/napapreport05.pdf).

<sup>13</sup> Chestnut, L.G. and Mills, D. A fresh look at the benefits and cost of the U.S. Acid Rain Program. *Journal of Environmental Management*. (article in press)

<sup>14</sup> Human Health Benefits from Sulfate Reduction under Title IV of the 1990 Clean Air Act Amendments. EPA-430-R-95-010.

significant benefits are not quantified, such as the 20 percent reduction in mercury emissions from power plants; improvements to urban visibility, forest health, and surface water quality; and increased longevity and reduced soiling of painted and stone surfaces.

The 2005 study finds that the estimated annual cost of the Acid Rain Program in 2010 is \$3 billion, with the SO<sub>2</sub> program accounting for about \$2 billion per year in 2010. These findings are generally consistent with other recent independent findings, and are far less than the original NAPAP estimates.<sup>15</sup> EPA expects NO<sub>x</sub> costs to be no more than \$1 billion annually, and likely less, from the limited analysis that has been completed in this area. This leads to a more than 40-to-1 benefit-cost ratio. Among the most important factors in reducing SO<sub>2</sub> program costs was improved transportation and production of coal, which enabled sources to increase the use of low-sulfur coal. The flexibility offered by the SO<sub>2</sub> program also may have enabled technological innovations that lowered compliance costs. For instance, boiler adaptations and lower than expected installation and operation costs for flue gas desulfurization systems (scrubbers) reduced costs below original estimates.<sup>16</sup>

**Figure 22: Human Health Benefits from Acid Rain Program PM<sub>2.5</sub> and Ozone Reduction**

Avoided Health Effects Related to Title IV's PM <sub>2.5</sub> and Ozone Reductions	Number of Cases Avoided*	Monetary Value—Millions (U.S. 2000\$)
<b>PM<sub>2.5</sub> Reduction</b>		
Mortality (adults)	18,000	\$106,171
Infant mortality (children less than 1)	100	\$779
Chronic bronchitis (adults)	11,000	\$4,274
Nonfatal heart attacks (adults)	24,000	\$2,018
Respiratory hospital admissions (all ages)	8,700	\$130
Cardiovascular hospital admissions (adults)	11,400	\$246
Emergency room visits for asthma (children)	14,700	\$4
Acute bronchitis (children)	27,700	\$10
Asthma exacerbations (children with asthma)	29,400	\$1
Upper respiratory symptoms (children with asthma)	353,400	\$9
Lower respiratory symptoms (children)	299,500	\$5
Minor restricted activity days (adults)	12,766,400	\$677
Work loss days (adults)	2,200,000	\$240
<b>Total related to PM<sub>2.5</sub> reduction</b>		<b>\$114,564</b>
<b>Ozone Reduction</b>		
Mortality	700	\$4,101
Respiratory hospital admissions (age ≥ 65)	1,500	\$27
Respiratory hospital admissions (age ≤ 2)	1,800	\$14
Emergency room visits for respiratory illness	400	\$0.1
School loss days	785,500	\$59
Acute respiratory symptoms, minor restricted activity	1,612,100	\$161
Worker productivity loss	n.a.	\$22
<b>Total related to ozone reduction</b>		<b>\$4,384</b>
<b>Total related to PM<sub>2.5</sub> and ozone reductions</b>		<b>\$118,949</b>

**Source:** Chestnut, L.G. and Mills, D. A fresh look at the benefits and cost of the U.S. Acid Rain Program. *Journal of Environmental Management*. (article in press)

\* Rounded to the nearest hundred

<sup>15</sup> See, for example:

Ellerman, D. (2003) *Lessons from Phase 2 compliance with the U.S. Acid Rain Program*. Cambridge, Massachusetts: MIT Center for Energy and Environmental Policy Research

Carlson, C.P., Burtraw, D., Cropper, M., and Palmer, K. SO<sub>2</sub> control by electric utilities: What are the gains from trade? *Journal of Political Economy*, Vol. 108, No. 6: 1292-1326.

Informing Regulatory Decisions: 2003 Report to Congress on the Costs and Benefits of Federal Regulations and Unfunded Mandates on State, Local, and Tribal Entities (2003) Office of Management and Budget, Office of Information and Regulatory Affairs: [www.whitehouse.gov/omb/inforeg/2003\\_cost-ben\\_final\\_rpt.pdf](http://www.whitehouse.gov/omb/inforeg/2003_cost-ben_final_rpt.pdf)

<sup>16</sup> EPA estimates recognize that some switching to lower-sulfur coal (and accompanying emission reductions) would have occurred in the absence of Title IV as railroad deregulation lowered the cost of transporting coal from Wyoming's Powder River Basin electric power plants in the Midwest and as plant operators adapted boilers to different types of coal.

## National Actions for Further Emission Reductions—2005 Clean Air Rules

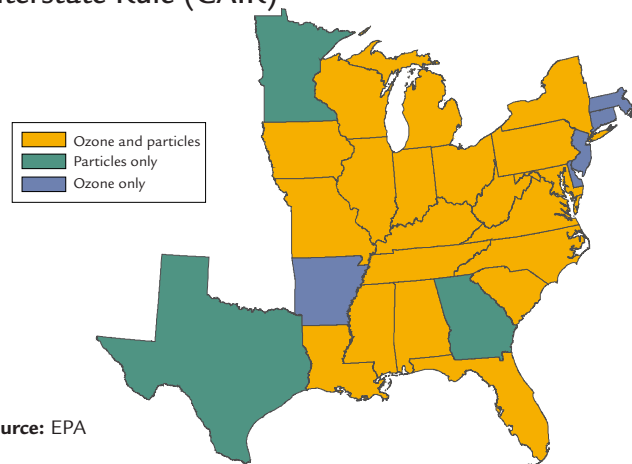
In the spring of 2005, in the absence of new legislation, EPA promulgated a suite of air quality rules designed to address additional reductions of SO<sub>2</sub>, NO<sub>x</sub>, and mercury (Hg) from power plants. These rules include the Clean Air Interstate Rule (CAIR), the Clean Air Mercury Rule (CAMR), and the Clean Air Visibility Rule (CAVR).<sup>17</sup>

CAIR will permanently lower and cap emissions of SO<sub>2</sub> and NO<sub>x</sub> in 28 eastern states and the District of Columbia (see Figures 23 and 24), starting in 2009 for NO<sub>x</sub> and 2010 for SO<sub>2</sub>. The rule addresses the transport of ozone and fine particles resulting from these emissions. States have the option to adopt a model cap and trade program administered by EPA to achieve the cap. The CAIR SO<sub>2</sub> trading program is designed to work with the existing Acid Rain Program. Sources turn in Acid Rain allowances at a ratio of greater than 1-to-1 to achieve reductions beyond Title IV of the Clean Air Act. When fully implemented, CAIR will reduce SO<sub>2</sub> emissions by over 70 percent and NO<sub>x</sub> emissions by over 60 percent from 2003 levels, leading to decreased particulate matter, ozone concentrations, and acid deposition. According to EPA models, CAIR will provide health and environmental benefits valued at more than 25 times the expected costs of compliance.<sup>17</sup>

CAMR is the first-ever rule to permanently cap and reduce mercury emissions from coal-fired power plants in all 50 states and the District of Columbia. CAMR establishes standards of performance limiting mercury emissions from new and existing coal-fired power plants and creates a cap and trade program to reduce nationwide utility emissions in two distinct phases. By 2018, a 15-ton cap will be in place. Along with the CAIR rule, this will result in a mercury reduction from coal-fired power plants of nearly 70 percent from current levels.<sup>17</sup>

CAVR applies to non-CAIR states, primarily in the West, and affects power plants and other major sources with the potential to impact visibility, fine particles, acid deposition, and ozone in certain areas of the country. CAVR places Best Available Retrofit

**Figure 23: States Covered by the Clean Air Interstate Rule (CAIR)**



Source: EPA

**Note:** EPA proposed in March 2005 to add Delaware and New Jersey to the states in CAIR covered for fine particles.

**Figure 24: CAIR/CAMR Emission Caps**

Air Emission Cap	CAIR (for 28 Eastern States and DC)	CAMR
SO <sub>2</sub> —Phase 1	3.6 million tons in 2010	
SO <sub>2</sub> —Phase 2	2.5 million tons in 2015	
NO <sub>x</sub> —Phase 1	1.5 million tons in 2009 (annual) 0.6 million tons 2009 (ozone season)	
NO <sub>x</sub> —Phase 2	1.3 million tons in 2015 (annual) 0.5 million tons 2015 (ozone season)	
Hg—Phase 1		38 tons in 2010
Hg—Phase 2		15 tons in 2018

Technology (BART), scrubbers for SO<sub>2</sub>, and advanced low-NO<sub>x</sub> burners, on many coal-fired units outside of the CAIR region in 2013/2014.<sup>17</sup>

Based on these three regulations, EPA estimates that power plants will install pollution control technology, such as scrubbers for SO<sub>2</sub> control and SCRs for NO<sub>x</sub> control. By 2010, nearly half (46 percent) of the units in the nationwide coal-fired fleet totaling roughly 146.3 GW of capacity will have installed scrubbers, while about 39 percent, or 126.5 GW of power plant capacity, will have installed SCRs. By 2020, nearly two-thirds (72 percent) of units will have scrubbers (230.5 GW of capacity) and over 56

<sup>17</sup> CAIR (See [www.epa.gov/cair/index.html](http://www.epa.gov/cair/index.html)), CAMR (See [www.epa.gov/air/mercuryrule/](http://www.epa.gov/air/mercuryrule/)), CAVR (See [www.epa.gov/oar/visibility/index.html](http://www.epa.gov/oar/visibility/index.html))

percent will have installed SCR (180.9 GW), according to EPA's projections.<sup>17</sup>

EPA projects that these rules will result in significant monetized health benefits (1999\$). These estimates range from \$62 billion to \$73 billion annually in 2010, and from \$120 billion to \$140 billion annually in 2020. The vast majority of these benefits result from the reduced levels of fine particles in the ambient air that will occur from reductions in SO<sub>2</sub> and NO<sub>x</sub> emissions. Reductions in SO<sub>2</sub> emissions from 1993 levels (by 4.3 million tons in 2010 and by 6.1 million tons in 2020) account for the largest portion of improvements in ambient fine particle conditions. The remaining benefits result from ozone improvements associated with NO<sub>x</sub> emission reductions. Notably, these rules also provide multiple unquantified benefits, including the value of increased agricultural crop and commercial forest yields, visibility improvements, reductions in nitrogen and acid deposition and the resulting changes in ecosystem functions, and health and welfare benefits associated with reduced mercury emissions.<sup>17,18</sup>

EPA expects that the air quality impacts of these regulations, coupled with recent rules to reduce fine particles and NO<sub>x</sub> from motor vehicles, will be extensive. Figures 25, 26, and 27 show areas projected to exceed NAAQS in 2010 and 2020, compared to today. Figure 25 shows ozone and PM<sub>2.5</sub> nonattainment areas primarily occurring in eastern states and California. As the new rules are implemented, nonattainment is expected to decline progressively, with 92 fewer areas by 2010 (see Figure 26), and 106 fewer areas by 2020 (see Figure 27).

As these maps indicate, implementing these three new regulations is an important step toward improving future air quality in the United States and helping states and local communities meet NAAQS for fine particles and ozone.

Future progress reports will begin to provide information important to the transition to CAIR, CAMR, and CAVR, while continuing to report on compliance under the Acid Rain Program.

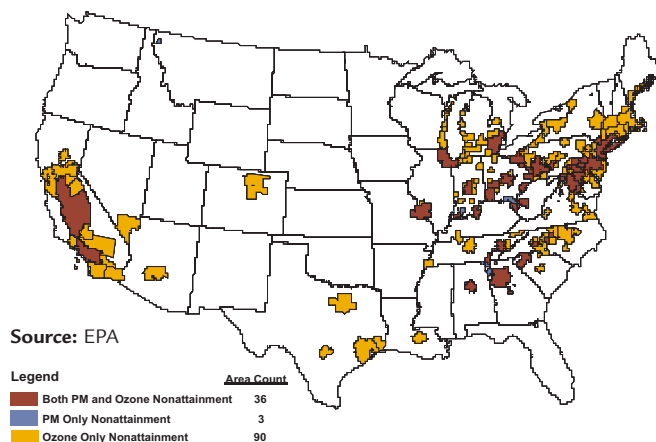
<sup>17</sup> CAIR (See [www.epa.gov/cair/index.html](http://www.epa.gov/cair/index.html)), CAMR (See [www.epa.gov/air/mercuryrule/](http://www.epa.gov/air/mercuryrule/)), CAVR (See [www.epa.gov/oar/visibility/index.html](http://www.epa.gov/oar/visibility/index.html))

<sup>18</sup> Multi-pollutant legislative analysis, October 2005, EPA

<sup>19</sup> Current rules include Title IV of CAA, NO<sub>x</sub> SIP Call, and some existing state rules.

<sup>20</sup> Areas forecast to remain in nonattainment may need to adopt additional local or regional controls to attain the standards by dates set pursuant to the Clean Air Act. These additional local or regional measures are not forecast here, and therefore this figure overstates the extent of expected nonattainment.

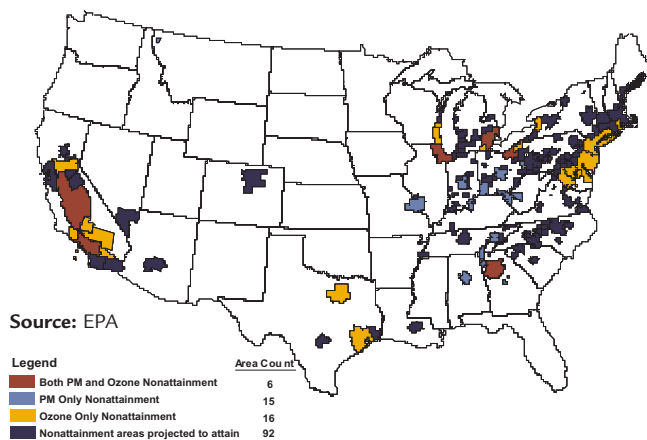
Figure 25: Current Nonattainment Areas



**Note:** Currently, 129 areas are designated as nonattainment for PM<sub>2.5</sub> and/or 8-hour Ozone (April 1, 2005).

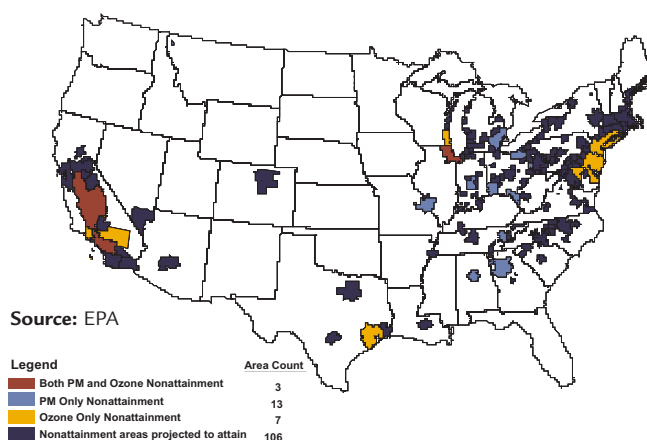
For further information on designations and related requirements, see [www.epa.gov/air/oaqps/glo/designations/index.htm](http://www.epa.gov/air/oaqps/glo/designations/index.htm) and [www.epa.gov/pmdesignations](http://www.epa.gov/pmdesignations).

Figure 26: PM<sub>2.5</sub> and Ozone Attainment in 2010



**Note:** 92 areas are projected to meet the PM<sub>2.5</sub> and 8-Hour Ozone Standards in 2010 with CAIR/CAMR/CAVR and some current rules, absent additional local controls.<sup>19,20</sup>

Figure 27: PM<sub>2.5</sub> and Ozone Attainment in 2020



**Note:** 106 areas are projected to meet the PM<sub>2.5</sub> and 8-Hour Ozone Standards in 2020 with CAIR/CAMR/CAVR and some current rules, absent additional local controls.<sup>19,20</sup>

# Online Information, Data, and Resources

## About the Clean Air Markets Division

The availability and transparency of data—from emission measurement to allowance trading to deposition monitoring—is a cornerstone of effective cap and trade programs. The Clean Air Markets Division in the Office of Air and Radiation's Office of Atmospheric Programs manages programs for collecting these data and assessing the effectiveness of cap and trade programs, including the Acid Rain Program.

[www.epa.gov/airmarkets](http://www.epa.gov/airmarkets)

## Regulatory Information

To learn more about how emissions cap and trade programs work, see:

[www.epa.gov/airmarkets/arp](http://www.epa.gov/airmarkets/arp)  
*Acid Rain Program*

[www.epa.gov/airmarkets/progsregs/noxview.html](http://www.epa.gov/airmarkets/progsregs/noxview.html)  
*NO<sub>x</sub> Trading Programs*

[www.epa.gov/airmarkets/capandtrade/index.html](http://www.epa.gov/airmarkets/capandtrade/index.html)  
*General Cap-and-Trade Information*

Also see recent related rulemakings, including:

[www.epa.gov/cair](http://www.epa.gov/cair)  
*Clean Air Interstate Rule (CAIR)*

[www.epa.gov/CAMR/index.htm](http://www.epa.gov/CAMR/index.htm)  
*Clean Air Mercury Rule (CAMR)*

[www.epa.gov/visibility](http://www.epa.gov/visibility)  
*Clean Air Visibility Rule (CAVR)*

## Progress and Results

Several reports have assessed the progress and results and projected future impacts of the Acid Rain Program.

[www.sciencedirect.com/science/journal/03014797](http://www.sciencedirect.com/science/journal/03014797)  
*A Fresh Look at the Benefits and Costs of the U.S. Acid Rain Program*

[www.al.noaa.gov/AQRS/reports/napapreport05.pdf](http://www.al.noaa.gov/AQRS/reports/napapreport05.pdf)  
*2005 National Acid Precipitation Assessment Program Report to Congress*

[www.rff.org/Documents/RFF-RPT-Adirondacks.pdf](http://www.rff.org/Documents/RFF-RPT-Adirondacks.pdf)  
*Valuation of Natural Resource Improvements in the Adirondacks*

[www.adirondacklakessurvey.org](http://www.adirondacklakessurvey.org)  
Jenkins, J., Roy, K., Driscoll, C., Beurkett, C.  
*Acid Rain and the Adirondacks: A Research Summary*. Adirondack Lakes Survey Corporation

## Emission, Allowance, and Environmental Data

For more information on emissions, allowance, and environmental data, see:

[cfpub.epa.gov/gdm](http://cfpub.epa.gov/gdm)  
*EPA Clean Air Markets Data and Maps*

[www.epa.gov/castnet](http://www.epa.gov/castnet)  
*Clean Air Status and Trends Network (CASTNET)*

[www.epa.gov/airmarkets](http://www.epa.gov/airmarkets)  
*2005 Atlas: Atmosphere in Motion*

[nadp.sws.uiuc.edu](http://nadp.sws.uiuc.edu)  
*National Atmospheric Deposition Program/ National Trends Network*



# A History of the Acid Rain Program

1970 – 1994

1970

20 million people celebrate the first Earth Day.



1970

Clean Air Act (CAA) is passed.

1977

Congress strengthens the CAA and includes requirements for SO<sub>2</sub> pollution control at power plants.

1978

The National Atmospheric Deposition Program/National Trends Network (NADP/NTN) begins monitoring sulfur and nitrogen and deposition to ecosystems.



1980

The National Acid Precipitation Assessment Program (NAPAP), mandated by Congress, begins study on acid rain.

1980

Lake acidification and fish loss in the Adirondacks, Green Mountains, and Sierra Nevada make national news.



1986

The United States and Canada begin study of cross-border acid rain transport. The United States is called upon to reduce emissions of SO<sub>2</sub> and NO<sub>x</sub>, especially from coal-burning power plants.

1987

The Clean Air Status and Trends Network (CAST-NET) is established to monitor dry deposition.

1990

Congress strengthens the CAA and establishes the Acid Rain Program using a market-based approach to reduce SO<sub>2</sub> from power plants by more than 50 percent.



1993

EPA publishes acid rain regulations, and Chicago Board of Trade holds first auction of SO<sub>2</sub> allowances.

1994

Projected costs of compliance re-estimated by the Government Accountability Office and the Electric Power Research Institute at less than half of original estimates.

## 1995 – 1999

### 1995

Phase I of Acid Rain Program implementation begins. SO<sub>2</sub> emissions fall to 5 million tons below 1980 levels. Acidity of rainfall in the eastern United States drops 10 to 25 percent.



### 1996

About 150 of the largest coal-fired power plants begin to implement Acid Rain Program NO<sub>x</sub> requirements.

### 1997

More than 80 percent of affected companies have engaged in private allowance transactions.



### 1998

Regulatory revisions enhance efficiencies of compliance and administration. Nearly 10 million economically significant allowance transfers take place.

### 1999

Allowance banking peaks. SO<sub>2</sub> early reductions total over 11 million tons.

## 2000 – 2005

### 2000

Phase II of Acid Rain Program begins, regulating additional smaller/cleaner plants and requiring further reductions in NO<sub>x</sub> and SO<sub>2</sub>.



### 2001

Introduction of the On-line Allowance Tracking System begins an era of paperless allowance transfer recording.

### 2002

EPA begins electronic audit process to supplement existing rigorous monitoring program.

### 2003

Lakes and streams in the Adirondacks, Upper Midwest and Northern Appalachian Plateau show signs of recovery.

### 2004

Acid Rain Program sources emit 34 percent less SO<sub>2</sub> and 43 percent less NO<sub>x</sub> than in 1990, despite a 34 percent increase in fuel usage.



### 2005

New study estimates 2010 annual Acid Rain Program benefits at \$122 billion and annual costs at \$3 billion. According to 2005 NAPAP report, further emission reductions are necessary to achieve broader environmental recovery. EPA promulgates CAIR, CAMR, and CAVR.



United States  
Environmental Protection Agency  
Office of Air and Radiation  
Clean Air Markets Division  
1200 Pennsylvania Ave, NW (6204J)  
Washington, DC 20460  
[www.epa.gov/airmarkets](http://www.epa.gov/airmarkets)

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EPA 430-R-05-012  
October 2005